STUDY OF THE PHYSICAL PROPERTIES OF THE HEN'S EGGSHELL IN RELATION TO THE FUNCTION OF SHELL-SECRETORY GLANDS.

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A hen's eggshell plays an important rôle in the development of the embryo. It gives a physical protection; governs the embryonic respiration, serving as a membrane in the free interchange of gases; and it is also of value in the embryonic metabolism, notably in the mineral metabolism. For example, the calcium in the embryo largely comes from the mineral portion of the eggshell.

Besides its importance to the embryo, the eggshell has a great bearing on the food value of eggs. The physical condition and the perishability of an egg's contents largely depend upon the physical quality of the eggshell. Thus, a thin, a rough, or a cracked shell allows easy penetration by bacteria and molds, loss of moisture and carbon dioxide, and absorption of outside odors. At the same time such a shell breaks easily in handling or in transit.

All the above factors seem to have been recognized by both the scientists, in the fields of physiology and nutrition, and the practical men, in the fields of poultry production and marketing of eggs. Yet up to the present time very little work has been done on the determination of the physical properties of the eggshell. Among the workers to be mentioned here is Rizzo ('99). He, in the study of twelve hen's eggs, found that the number of pores per square millimeter of shell surface varied from 0.86 to 1.44 with an average of 1.23.

The present investigation concerns itself with the breaking strength, thickness, and porosity of the hen's eggshell, in relation to the function of the shell-secretory glands.

METHODS AND MATERIALS.

All the eggs used were from a flock of 91 White Leghorn pullets. During the experimental period of 16 weeks (from December 10, 1924, to March 31, 1925) the flock laid 3,998 normal

eggs. Production varied from 2 to 79 eggs per hen. The eggs were tested, the day that they were laid, for breaking strength and for thickness of eggshell. The breaking strength was measured by applying pressure to both ends of the egg in a specially constructed eggshell-testing machine (Fig. 1). The thickness was

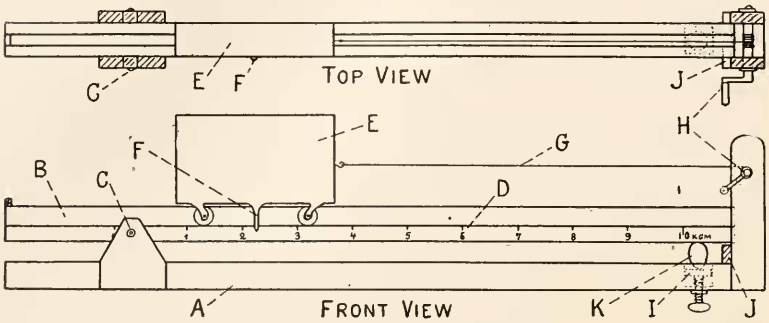

FIG. 1. A diagram of the eggshell-testing machine. *A*, frame; *B*, lever; *C*, fulcrum; *D*, scale; *E*, carriage; *F*, pointer; *G*, string; *H*, winch; *I*, adjusting stand; *J*, safety pin; *K*, egg.

measured by the micrometer caliper with ratched stop. Many eggs were also observed for the size and the location of pores on both the outer and inner surfaces of the eggshell.

RESULTS AND DISCUSSION.

The experimental data show that the breaking strength of the eggshell varies greatly not only among individual eggs but also among hens. The highest breaking strength was found to be 8.5 kilograms, while the average for 3,998 eggs was 4.46 kilograms. It was also determined that the average breaking strength of eggshell was less by one to two kilograms if the eggs were broken by applying pressure on the sides instead of the ends of the eggs. The tested eggs usually broke either on the blunt or on the pointed end, but very seldom on both ends at the same time. Of the whole number, 48 per cent. broke on the blunt end, and 52 per cent. on the pointed end.

The frequency distribution of variation in breaking strength is illustrated in Table I.

Table I.

Frequency Distribution of Variation in Breaking Strength of Eggshell.

Breaking Strength (Kgm.).	Frequency Occurrence.		
	Number of Hens.	Number of Observations.	Number of Eggs per Hen.
2.01–2.40	1	2	2.0
2.41–2.80	1	37	37.0
2.81–3.20	3	117	39.0
3.21–3.40	7	224	32.0
3.41–4.00	9	329	36.6
4.01–4.40	20	848	42.4
4.41–4.80	23	1,097	47.6
4.81–5.20	18	858	47.7
5.21–5.60	8	439	54.9
5.61–6.00	1	47	47.0
Total	91	3,998	—

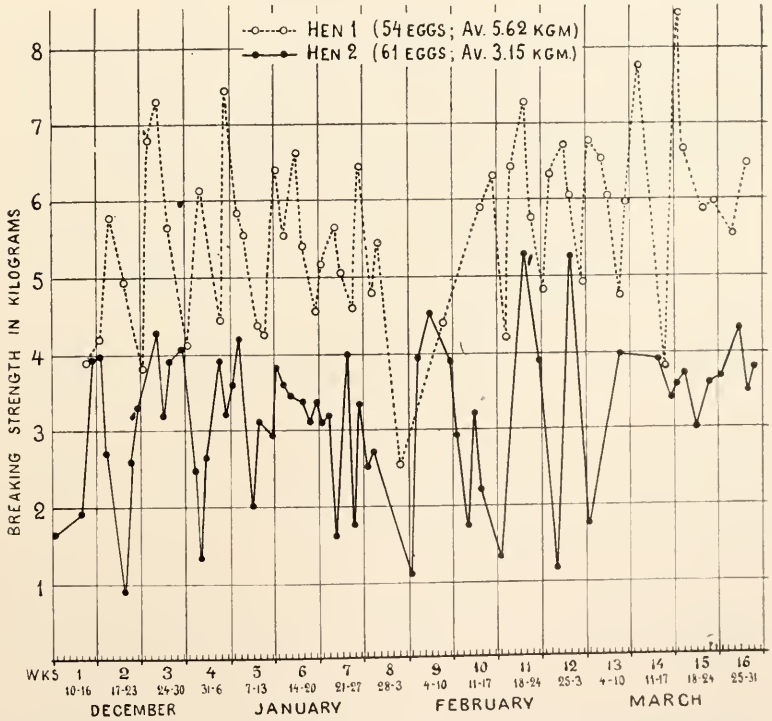

Fig. 2. Comparison of the breaking strengths of eggshell from two hens laying during the entire (16 weeks) period of observation.

The largest number of hens was found to be in the group averaging 4.4 to 4.8 kilograms. The number of eggs per hen, or the index of production, shows an increase with the strength of eggshell. In other words, the egg production stimulates the normal function of the reproductive organs and the eggshell secretory glands as well.

There is enough evidence to prove that the strength of eggshell varies with individuals. Figure 2 demonstrates a typical case, when two hens of almost equal production give a quite uneven average for the breaking strength of eggshell; the individual curves run distinctly apart throughout the observation period. The above figure and numerous observations by other individuals, show that the strength of eggshell is more uniform during a cycle of heavy egg production. Evidently, the secretary glands work normally at such times; and in practice, therefore, it would be advisable to select the hen for the strength of eggshell.

TABLE II.

RELATION BETWEEN BREAKING STRENGTH AND THICKNESS OF EGGSHELL.

Breaking Strength.	Thickness.			
	Broken End.	Unbroken End.	Blunt End.	Pointed End.
Kgm.	mm.	mm.	mm.	mm.
2.01–2.40	—	—	—	—
2.41–2.80	.246	.284	.290	.244
2.81–3.20	.259	.285	.287	.259
3.21–3.60	.274	.292	.291	.277
3.61–4.00	.287	.295	.292	.295
4.01–4.40	.302	.315	.312	.307
4.41–4.80	.325	.325	.325	.325
4.81–5.20	.333	.348	.333	.347
5.21–5.60	.343	.358	.343	.358
5.61–6.00	.356	.366	.345	.373
Average	.303	.319	.313	.309

Table II. indicates that the thickness is in direct relation to the breaking strength of the eggshell. The average thickness of all eggs was 0.311 millimeters. Eggs approaching this average had an almost equal thickness at both ends; while in general the broken end was thinner than the unbroken, and the blunt end was

thicker than the pointed. The pointed end, being the posterior part of the egg during its formation, gets comparatively less accumulation of the material in a weak and more in a strong eggshell.

The external structure of the eggshell, as seen under magnification (Fig. 3), suggests that a strong, thick eggshell has a large

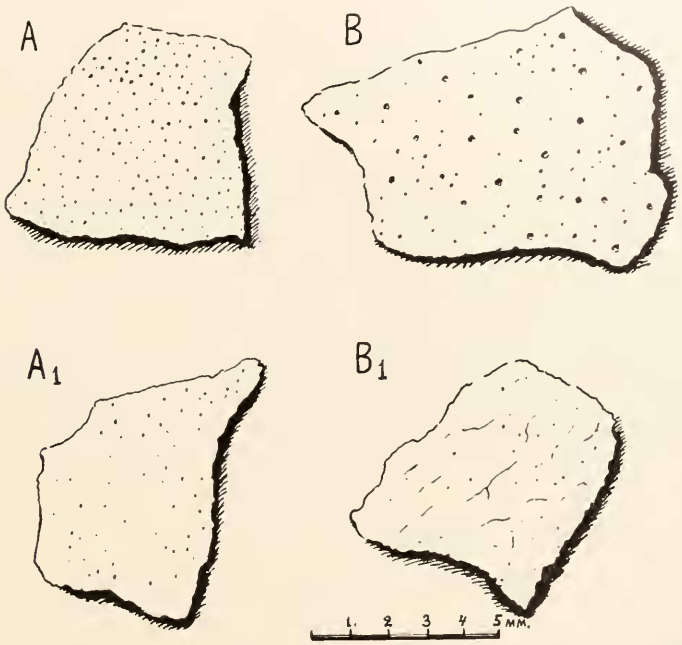

FIG. 3. Size and number of pores of eggshell as seen under magnification. A, outer, A_1, inner surface of a strong, thick eggshell. B, outer and B_1, inner surface of a weak, thin eggshell.

number of minute pores; while a weak, thin eggshell has few pores, but some of these are quite large in size. Besides, the inner surface of a weak eggshell has many grooves of various depths. Observation of the outer surface of the eggshell for the number and size of pores, may guide us in judging the breaking strength and thickness of the eggshell.

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Summary.

1. The data from 3,998 eggs show that the breaking strength and the thickness of eggshell are in the average 4.46 kilograms and 0.311 millimeters.

2. There exists a positive relation between the breaking strength and the thickness of an eggshell.

3. The breaking strength and the thickness of eggshell vary with individuals.

4. The variation of breaking strength and thickness of eggshell is the least at the time of heavy egg production. Therefore, the mean value of either the breaking strength or the thickness of eggshell may be easily determined by a few observations during the cycle of heavy egg production.

5. The porosity vary with the breaking strength and thickness of eggshell. The pores of the thick shell are small and numerous, while those of the thin shell are large and few in number.

6. The physical properties of eggshell presumably depend upon the individual function of the secretory glands during egg formation more than any other external factors.

REFERENCE.

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